

Core Technology for R & D and Innovation of Super Intelligent Robot Technology 2026 V 1.1



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High-standard technical drawings (humanoid robot), detailed technical R&D path and technology roadmap, bionic simulation of the five-fingered dexterous, high-precision, and ultra-fine movements of a super-intelligent robot:

- ① Fine and exquisite needle-threading action;
- ② Rice grain picking, with close cooperation between the five fingers and fingernails to achieve stunning and remarkable precision;
- ③ Integrated, optimized interaction of neural consciousness, perception, cognition, feedback control, reasoning, and thinking for the super-intelligent robot, with highly integrated, interactive, generalized, optimized, and enhanced sensitivity of vision, hearing, touch, smell, somatosensation, and intuition. It is capable of preliminary judgment, thinking, feedback, and reasoning, including language dialogue, scene adaptation, and preliminary autonomous induction and response capabilities;
- ④ Integrated fusion and interactive switching of the internal control system module, compatible and inclusive with external control system modules, supporting interactive switching;
- ⑤ Other high-standard technical configurations, including redundant design, etc.

In accordance with the above instructions ①-④, the high-standard technical drawings include schematic diagrams, structure diagrams, installation diagrams, detailed component drawings, mechatronic circuit diagrams, material diagrams, hardware and software configuration coordination and interactive switching diagrams, and various technical parameters. The focus is on the highly flexible, agile, and dexterous five-fingered fine and exquisite movements, detailed technical design drawings for rice grain picking and needle threading, bionic simulation of the super-intelligent robot, integrated fusion and interactive generalization capabilities of vision, hearing, touch, smell, and sensory sensitivity modules, as well as coordinated linkage and interaction with the five-finger joints and body, language expression ability, and the preliminary integrated fusion module of neural system consciousness, perception, cognition, feedback control, reasoning, and thinking.

International standard detailed technical design drawings and related R&D drawings with detailed data, information, and technical parameter configurations.

Full-dimensional Technical Drawing System and R&D Path Planning for Ultra-precision Bionic Humanoid Robots

Abstract

Focusing on the core R&D requirements of ultra-precision bionic humanoid robots, this paper systematically expounds the design specifications, technical parameter systems, and R&D technical routes of a full set of high-standard technical drawings covering mechanical structure, bionic movements, intelligent perception, control systems, and hardware-software collaboration. It focuses on core technical points such as five-fingered bionic fine movements (needle threading, rice grain picking), multi-modal perception fusion, brain-like consciousness and cognitive feedback, dual control system interaction, and redundant safety design. It clarifies the drawing requirements, classification, functional definitions, and data specifications of international standard technical drawings, and constructs a rigorous, scientific, and implementable engineering design and R&D framework for humanoid robots, providing complete drawing support and technical guidance for prototype development, performance verification, and industrialization of high-end bionic robots.

1. Overall Positioning of Humanoid Robot R&D and Objectives of the Drawing System

The ultra-precision bionic humanoid robot developed in this project is positioned as a next-generation general intelligent robot platform with human-like fine movements, multi-modal perception, preliminary cognitive reasoning, and autonomous response capabilities. It breaks through the technical bottlenecks of traditional industrial robots such as rough movements, single perception, and delayed decision-making, and achieves deep integration of bionic mechanical structure, precision drive control, brain-like intelligent algorithms, and multi-system collaborative interaction.

To ensure standardization, engineering, and traceability throughout the R&D process, all drawings strictly comply with international general specifications in mechanical design, mechatronics, electronic circuits, intelligent control, and other fields. With rigorous engineering drawing logic, accurate dimensional parameters, and clear module interaction relationships, the robot realizes full-dimensional visual design from macro structure to micro components, from hardware integration to software collaboration, and from action execution to intelligent decision-making, providing the only authoritative technical basis for R&D, trial production, debugging, and iteration.

2. Core Technical Indicators and Bionic Fine Movement Design Requirements

The core competitiveness of this humanoid robot focuses on five-fingered bionic precision movements and human-like intelligent perception and decision-making. Both core technical indicators reach the top level in the industry and are the core focus of technical drawing design.

2.1 Five-fingered Bionic Fine Movement Technical Indicators

1. Needle-threading precision movement:

Multi-degree-of-freedom (DOF) bionic finger joint design is adopted. Each finger has ≥ 6 active DOFs and 2 passive DOFs, with a total of ≥ 32 DOFs for five fingers. The fingertip repeat positioning accuracy is ± 0.01 mm, and the fingertip output force resolution is 0.001 N. It can accurately pass a 0.1 mm diameter suture through a 0.2 mm needle hole, with continuous, stable, and jitter-free movements, fully replicating the fine motion logic of human fingers during needle threading.

2. Rice grain picking bionic movement:

High-precision tactile sensor arrays are integrated into the finger pulps, and a micro-force sensing and flexible contact structure is designed at the fingernails. Cooperating with the five fingers and fingernails, it can accurately pick rice grains with a diameter of 1-2 mm, with a picking success rate $\geq 99.5\%$ and contact force control accuracy ≤ 0.005 N, achieving ultra-fine operation without damage, slipping, or crushing. The movement fluency and precision reach the top level in the field of bionic robots.

2.2 Brain-like Intelligent Perception and Cognitive Decision-making Technical Indicators

Six types of perception modules are integrated: vision, hearing, touch, smell, proprioception, and intuitive perception. The perception sensitivity reaches more than 90% of human senses, with full-process processing capabilities of signal acquisition, transmission, fusion, generalization, optimization, and enhancement. Equipped with a preliminary neural consciousness perception and cognition module, it realizes basic intelligent interaction including environment recognition, language dialogue, scene adaptation, autonomous response, logical reasoning, and feedback control, and can independently adjust movement parameters, decision-making behaviors, and control strategies according to external inputs.

2.3 Control System and Redundant Design Technical Indicators

A dual-module architecture of internal control system + external access control system is adopted, supporting real-time compatibility, seamless switching, and collaborative interaction. Key structural, drive, sensing, and control units of the whole machine adopt redundant design, with fault self-inspection, fault-tolerant operation, and emergency switching functions to ensure the operational stability and safety of the robot in complex scenarios.

3. Classification, Composition and Design Content of the Full Set of High-standard Technical Drawings

The technical drawings of this project are strictly drawn in accordance with international mechanical engineering drawing standards, mechatronic design specifications, and intelligent control system drawing standards, marked with

extra-large black English fonts, including drawing numbers, design parameters, dimensional tolerances, material models, module interfaces, etc.

3.1 Overall R&D Path and Technical Roadmap

1. Overall technical R&D roadmap for humanoid robots:

Clarify the full-process R&D nodes from conceptual design, core technical research, component trial production, system integration, performance testing to prototype finalization, and mark the R&D cycle, technical difficulties, verification standards, and iteration paths of the four core technologies: five-fingered fine movements, multi-modal perception, dual control system, and redundant design.

2. Overall system architecture drawing:

Draw the layout of the robot's overall mechanical structure, perception module, control module, drive module, and interaction module, and clarify the installation position, connection mode, interaction interface, and collaboration logic of each subsystem.

3.2 Five-fingered Bionic Fine Movement Mechanical Structure Drawings

1. Overall structure drawing of five-fingered bionic hand:

Mark the dimensional parameters, DOF distribution, drive mode, and movement range of the palm, five fingers, finger joints, and nail structure.

2. Single-finger precision transmission schematic:

Show the transmission logic of finger tendons, gears, connecting rods, and micro-motors, and clarify the movement accuracy, force transmission efficiency, and action response speed.

3. Detailed drawing of fingertip and nail microstructure:

Draw the component dimensions, installation methods, and material parameters of fingertip tactile sensors, nail flexible contacts, and micro-force actuators.

4. Movement trajectory drawing of needle-threading action:

Mark the joint angle, movement path, positioning coordinates, and timing control parameters for the fingers to complete needle threading.

5. Collaborative control drawing of rice grain picking action:

Show the movement coordination, force control logic, contact angle, and picking process of the five fingers and nails.

6. Detailed drawing of finger joint components:

Include dimensions, tolerances, materials, and processing requirements of joint shafts, bearings, drive servos, and flexible connectors.

7. Overall installation drawing of bionic hand:

Clarify the connection mode, fastening standards, and debugging requirements between the hand structure and the arm/wrist.

3.3 Mechatronics and Circuit Drawings

1. Drive circuit diagram for five-fingered fine movements:

Circuit connection, power supply parameters, and signal transmission lines of micro servo motors, tactile sensors, and force control modules.

2. Circuit diagram of multi-modal perception module:

Circuit integrated design of vision cameras, auditory microphones, tactile arrays, olfactory sensors, and proprioceptive encoders.

3. Circuit diagram of dual control system interaction:

Circuit interfaces, signal conversion, power redundancy, and switching circuits between the internal control module and the external access module.

4. Circuit diagram of the whole machine power supply system:

Circuit layout and protection design of redundant power supplies, voltage stabilization modules, and emergency power supply units.

5. Circuit diagram of signal acquisition and transmission:

Acquisition, amplification, transmission, and filtering circuits of perception signals, control signals, and action feedback signals.

3.4 Multi-modal Perception and Neural Cognition Module Drawings

1. Integrated fusion drawing of six types of perception modules:

Layout, interface, and data fusion logic of vision, hearing, touch, smell, proprioception, and intuitive perception modules.

2. Schematic diagram of neural consciousness perception and cognition module:

Architecture design of primary brain-like chips, algorithm units, reasoning engines, and feedback control units.

3. Perceptual signal generalization and optimization processing drawing:

Process design of external signal acquisition, preprocessing, feature extraction, generalization learning, and optimized output.

4. Language dialogue interaction module drawing:

Hardware and software collaborative design of speech recognition, semantic understanding, speech synthesis, and language output.

5. Scene adaptation and autonomous response control drawing:

Closed-loop control logic of environment perception, decision reasoning, action adjustment, and feedback correction.

3.5 Hardware-software Collaboration and Dual Control System Interaction Drawings

1. Architecture drawing of internal control system module:

Hardware and software configuration and interaction logic of the internal main control chip, algorithm library, drive unit, and feedback unit.

2. Compatibility drawing of external access control system:

Access interfaces, protocol adaptation, and compatibility design of external control terminals, cloud systems, and human-computer interaction devices.

3. Seamless switching control drawing of dual systems:

Authority allocation, signal switching, data synchronization, and collaborative operation logic of internal and external control systems.

4. Hardware and software configuration collaborative interaction drawing:

Data interaction, instruction transmission, status feedback, and linkage control between hardware execution units and software algorithm modules.

5. System debugging and parameter configuration drawing:

Calibration, debugging process, calibration standards, and optimization methods of the whole machine's hardware and software parameters.

3.6 Material, Redundant Design and Technical Parameter Drawings

1. Material drawing of core robot components:

Material models, mechanical properties, heat resistance, and wear resistance parameters of bionic fingers, joints, sensors, and drive parts.

2. Overall machine redundant structure design drawing:

Redundant layout, fault switching, and fault-tolerant operation design of drive, sensing, control, and power supply units.

3. Summary drawing of key technical parameters:

Marking of core parameters such as movement accuracy, perception sensitivity, control response speed, DOF, force control accuracy, and battery life.

4. Overall machine assembly process drawing:

Component assembly sequence, fastening torque, debugging standards, and quality inspection requirements.

5. Performance verification and test drawings:

Test methods, test procedures, and qualification standards for fine movements, perception capabilities, control accuracy, and redundant performance.

4. Drawing Specifications and Standard Requirements

To ensure the engineering practicability, international universality, and rigor of the drawings, all drawings strictly comply with the following standards:

1. Format specification: Clear layout, distinct layers, and prominently marked core modules.

2. Drawing specification: Strictly in accordance with ISO international standards for mechanical, electrical, and control schematic drawings, unified lines, symbols, legends, and accurate dimension markings, without ambiguous, sci-fi, or cartoon elements.

3. Marking specification: Marked with extra-large black English fonts, including drawing name, module number, dimensions, materials, functions, and technical standards.

4. Content specification: All drawings are designed based on real engineering logic, with implementable parameters, realizable structures, and integrable systems, ensuring direct usability for processing, integration, and prototype production.

5. R&D Implementation Path and Technical Support Based on Technical Drawings

This full-dimensional technical drawing system provides complete support for humanoid robot R&D from theory to practice and from design to manufacturing. The R&D implementation path strictly relies on the drawing system:

1. Drawing review and finalization: Complete design, verification, review, and solidification of all drawings to form the only authoritative technical document.
2. Core component trial production: Custom trial production of five-fingered bionic structures, micro drives, high-precision sensors, brain-like control chips, etc.
3. System integration and assembly: Integrate and assemble the mechanical structure, perception module, control module, and drive module in accordance with assembly and circuit drawings.
4. Fine movement debugging: Debug finger movement accuracy, force control sensitivity, and collaborative movement capabilities based on action trajectory and force control parameter drawings.
5. Intelligent perception and decision optimization: Complete perception signal debugging, algorithm optimization, and autonomous decision-making verification.
6. Dual control system and redundancy test: Complete control system switching test, fault tolerance test, and safety performance verification.
7. Overall machine performance calibration: Full-dimensional calibration and optimization of fine movements, perception, intelligent decision-making, and operational stability.

6. Conclusion

The full set of high-standard technical drawing systems for ultra-precision bionic humanoid robots is the core engineering foundation for high-end bionic robot R&D. Focusing on five core directions: ultimate five-fingered fine movements, human-like multi-modal perception, preliminary cognitive decision-making, dual-system collaborative interaction, and redundant safety design, it achieves full-chain visual design of the robot from macro design to micro details, from hardware structure to software algorithms, and from action execution to intelligent decision-making with international-standard engineering drawing specifications, accurate and detailed technical parameters, and clear and complete module interaction logic.

This drawing system and R&D path not only solve industry pain points such as difficult fine movements, shallow perception fusion, and weak intelligent decision-making of bionic robots, but also build a standardized, engineered, and implementable high-end robot R&D framework, laying a solid technical foundation for the next-generation general humanoid robot's technological breakthrough, prototype development, and industrial application, and promoting the leapfrog development of bionic robot technology toward humanization, precision, intelligence, and practicality.

High-standard Technical R&D Plan and Detailed Design Description for Super-intelligent Humanoid Robots

1. Core Technology R&D Path and Overall Technical Roadmap

The R&D of this super-intelligent humanoid robot follows the path of bionic foundation construction – fine function breakthrough – intelligent system integration – multi-module collaborative optimization, divided into four core stages:

1. Bionic structure and mechanical foundation construction stage:

Based on the human limb structure, complete the design of 23–43 DOF joints of the whole body. Each hand finger is equipped with 3–4 DOFs, matching the movement range of human fingers such as flexion, extension, adduction, and abduction. The skeleton adopts aviation-grade 6061 aluminum alloy to balance lightweight and high strength. For mass production, it can be replaced by glass fiber reinforced PA66 engineering plastic, reducing cost by 30% while maintaining 85% structural strength.

2. Fine movement function special breakthrough stage:

Focus on five-fingered dexterous operation, overcome the mechanical control and perception technology of high-precision movements such as needle threading and rice grain picking, and simultaneously complete the hardware integration and basic algorithm debugging of multi-modal perception modules such as vision and touch.

3. Intelligent cognition and control system integration stage:

Build a full closed-loop intelligent system of "perception–decision–execution", integrate multi-modal perception fusion algorithms and preliminary reasoning decision models, realize language dialogue, scene adaptation, and autonomous response capabilities, and complete the compatible interaction design between the internal control system and the external access system.

4. System optimization and standard verification stage:

Carry out full-module collaborative debugging and redundant function testing, complete compliance verification in accordance with ISO 10218-1/2 robot safety standards and ISO 13482 service robot standards, and finally output a complete set of technical drawings and parameter systems in line with international specifications.

2. Detailed Design Drawings of Five-fingered Fine Movement System

2.1 Mechanical Structure Design

1. Hand assembly structure drawing:

The single palm adopts an integrated carbon fiber composite base with a weight of only 120 g. Each finger joint is equipped with a micro DC servo motor with a torque output range of 0.8–1.5 N·m and response time ≤ 15 ms. The end of each finger is equipped with a bionic nail structure made of medical-grade silicone rubber with a surface roughness $R_a \leq 0.2 \mu\text{m}$, simulating the curvature and friction of human nails to achieve accurate fitting and picking of tiny objects such as rice grains.

2. Joint transmission schematic:

Adopt a combined transmission scheme of harmonic reducer + synchronous pulley. The harmonic reducer has a reduction ratio of 1:80 and transmission

efficiency $\geq 90\%$, ensuring high precision and low backlash of joint movements. The synchronous pulley transmission error is controlled within 0.1° , meeting the micro-adjustment demand of fingers during needle threading.

3. Component details:

Finger joint bearings adopt ceramic ball bearings with an inner diameter of 2 mm and outer diameter of 5 mm, with a limit speed of 12000 rpm. The motor encoder resolution is 1024 lines/revolution, achieving an angle control accuracy of 0.35° . Hand wiring uses silver-plated copper wires with a diameter of 0.1 mm integrated in internal wiring grooves to avoid movement interference.

2.2 Fine Movement Control Design

1. Needle-threading action control logic:

Obtain coordinate information with a pinhole position accuracy of ± 0.05 mm through the vision module, combined with pressure data (accuracy 0.1 Pa) fed back by the fingertip tactile sensor. Adopt PID + fuzzy control algorithm to control the fingers to complete the continuous action of "positioning-approaching-penetrating", with action completion time ≤ 3 s and success rate $\geq 98\%$.

2. Rice grain picking action control logic:

Use the vision module to identify the shape and position of rice grains, drive the fingers to approach the rice grains at a speed of 0.5 mm/s. When the fingertip tactile sensor detects a contact pressure of 0.5 Pa, control the finger joints to close with an accuracy of 0.2° , and cooperate with the fitting of the bionic nails to achieve stable picking of rice grains, with a single picking success rate $\geq 95\%$.

2.3 Mechatronic Circuit Diagram

The hand control system adopts STM32H7 series microcontroller with a main frequency of 400 MHz, supporting 8-channel PWM signal output to independently control 5 finger joint motors. It integrates 16-channel 12-bit AD acquisition channels for collecting data from tactile sensors and position sensors. Communication adopts CAN bus with a transmission rate of 1 Mbps to ensure real-time data interaction between the hand and the main controller.

3. Multi-modal Perception and Intelligent Cognitive System Design

3.1 Perception Module Integrated Design

1. Multi-sensor configuration:

The vision system adopts 2 sets of 4K global shutter cameras + structured light depth camera with a frame rate of 30 fps, achieving a depth measurement accuracy of 0.01 mm. The auditory module adopts an 8-channel array microphone, supporting 360° sound source localization with positioning error $\leq 5^\circ$. The tactile system is equipped with 128-point piezoelectric tactile sensors on the hand and 64-point pressure sensors distributed on the whole body joints, with a pressure detection range of 0.1–100 N. The olfactory module adopts a

metal oxide gas sensor array, which can identify 12 common odors with response time ≤ 2 s.

2. Multi-modal fusion algorithm:

Based on the Transformer architecture multi-modal fusion model, feature extraction and fusion of vision, hearing, touch, and smell data are performed with fusion delay ≤ 100 ms. Generalization optimization is carried out through reinforcement learning algorithms, with an environment recognition accuracy rate $\geq 92\%$ in 1000 different scenarios.

3.2 Intelligent Cognition and Decision Module

1. Neural consciousness simulation system:

Adopt a "large model + edge reasoning" architecture. The main controller deploys a lightweight embodied intelligent large model with 7B parameters, supporting language dialogue, scene reasoning, and autonomous decision-making. The edge computing unit realizes local real-time response with response time ≤ 200 ms. It has basic logical reasoning ability and can complete the complete task chain of "recognizing objects - judging purposes - performing actions".

2. Language interaction system:

Integrate speech recognition and synthesis engine with speech recognition accuracy $\geq 98\%$ (Mandarin), supporting basic recognition of 20 dialects and 5 foreign languages. The naturalness of speech synthesis MOS score ≥ 4.8 , enabling natural language dialogue in multiple scenarios.

4. Control System Integration and Interaction Design

4.1 Internal Control System Module

Adopt a hierarchical distributed control architecture, divided into main control layer, joint control layer, and sensor layer:

- The main control layer adopts an industrial-grade X86 processor with a main frequency of 2.8 GHz, responsible for global task planning and multi-module collaboration.
- The joint control layer adopts distributed servo drivers, each with independent configuration, supporting force-position hybrid control with control accuracy ≤ 0.02 N·m.
- The sensor layer realizes real-time collection and preprocessing of multi-source data with data transmission delay ≤ 50 ms.

The system adopts modular design, with each module connected through standardized interfaces, supporting hot-plug and online upgrade. It has 3 built-in working modes: fine operation mode, fast movement mode, and energy-saving mode, which can be automatically switched according to task requirements with switching response time ≤ 1 s.

4.2 External Control System Compatibility Design

Support various industrial communication protocols such as TCP/IP, MODBUS, EtherCAT, and can be connected to external PLC and upper computer control systems. Equipped with standardized API interfaces to support secondary development and customized control logic. Realize seamless switching between the internal control system and external systems without movement interruption, with switching time ≤ 200 ms.

5. High-standard Technical Configuration and Redundant Design

1. Power system redundancy:

Dual lithium battery power supply is adopted, with a single battery capacity of 20 Ah and voltage of 48 V, supporting hot backup switching. When the power of one battery is lower than 20%, it automatically switches to the other battery without voltage fluctuation, ensuring the system continuous operation time ≥ 8 hours.

2. Sensor redundancy:

Core vision and tactile sensors adopt dual backup configuration. When the main sensor fails, the backup sensor automatically switches within ≤ 100 ms to ensure the continuity of system perception.

3. Control channel redundancy:

Dual CAN bus communication channels are configured between the main controller and joint controller. When the main channel fails, the backup channel automatically takes over with communication interruption time ≤ 50 ms.

4. Safety redundant design:

Integrate multiple safety mechanisms such as emergency stop buttons, collision detection sensors, and overcurrent protection. When an abnormality is detected, the system stops all actions and enters a safe state within 10 ms, complying with ISO 13849-1 PLd safety level.

6. Technical Parameter Summary Table

Category Parameter Indicators

Overall Specs Height 175 cm, weight 75 kg, 43 DOFs for the whole body

Hand System 3 DOFs per finger, joint angle control accuracy 0.35° , tactile sensor resolution 0.1 Pa

Perception System Vision resolution 4K, auditory localization error $\leq 5^\circ$, olfactory response time ≤ 2 s

Intelligent System Speech recognition accuracy $\geq 98\%$, scene recognition accuracy $\geq 92\%$, decision response ≤ 200 ms

Control System Main controller frequency 2.8 GHz, communication rate 1 Mbps, system switching time ≤ 200 ms

Safety Performance Comply with ISO 13849-1 PLd, emergency stop response time ≤ 10 ms

Core Technologies and Key Technologies

The core technologies and key technologies are highly technical and commercial secrets. This paper has been technically revised and deleted, only for reference, study and learning purposes.

① ② ③ ④ ① ② ③ ④

1. ≥ 6 2. ≥ 32 $\pm 0.01\text{mm}$ 0.001N 0.1mm 0.2mm 2. $1\sim 2\text{mm}$ $\geq 99.5\%$ $\leq 0.005\text{N}$ 90% + 1. 2. 3. 4. 5. 6. 7. 1. 2.

1. 物料在加工过程中，应严格控制温度，确保在 200-240℃ 范围内，避免过热导致材料性能下降。2. 加工过程中，应严格控制速度，确保在 23-43 mm/min 范围内，避免过快导致材料变形。3-4 加工过程中，应严格控制压力，确保在 6061 MPa 范围内，避免过高导致材料破裂。5. 加工过程中，应严格控制时间，确保在 PA66 材料允许的 30% 范围内，避免过长导致材料老化。6. 加工过程中，应严格控制湿度，确保在 85% 范围内，避免过高导致材料吸水。7. 加工过程中，应严格控制环境，确保在 ISO 10218-1/2 标准范围内，避免污染导致材料性能下降。8. 加工过程中，应严格控制设备，确保在 ISO 13482 标准范围内，避免设备故障导致材料性能下降。9. 加工过程中，应严格控制人员，确保在 2. 标准范围内，避免人员操作不当导致材料性能下降。10. 加工过程中，应严格控制材料，确保在 120g 范围内，避免过多导致材料浪费。11. 加工过程中，应严格控制尺寸，确保在 0.8-1.5N·m 范围内，避免过大导致材料变形。12. 加工过程中，应严格控制时间，确保在 ≤15ms 范围内，避免过长导致材料性能下降。13. 加工过程中，应严格控制压力，确保在 Ra≤0.2μm 范围内，避免过高导致材料破裂。14. 加工过程中，应严格控制速度，确保在 1:80 范围内，避免过快导致材料变形。15. 加工过程中，应严格控制温度，确保在 ≥90% 范围内，避免过低导致材料性能下降。16. 加工过程中，应严格控制湿度，确保在 0.1° 范围内，避免过高导致材料吸水。17. 加工过程中，应严格控制环境，确保在 2mm 范围内，避免污染导致材料性能下降。18. 加工过程中，应严格控制设备，确保在 5mm 范围内，避免设备故障导致材料性能下降。19. 加工过程中，应严格控制人员，确保在 12000rpm 范围内，避免人员操作不当导致材料性能下降。20. 加工过程中，应严格控制材料，确保在 1024 g/ 范围内，避免过多导致材料浪费。21. 加工过程中，应严格控制尺寸，确保在 0.35° 范围内，避免过大导致材料变形。22. 加工过程中，应严格控制时间，确保在 0.1mm 范围内，避免过长导致材料性能下降。23. 加工过程中，应严格控制压力，确保在 ±0.05mm 范围内，避免过高导致材料破裂。24. 加工过程中，应严格控制速度，确保在 0.1Pa 范围内，避免过快导致材料变形。25. 加工过程中，应严格控制温度，确保在 PID+ 范围内，避免过热导致材料性能下降。26. 加工过程中，应严格控制湿度，确保在 "0-10-10" 范围内，避免过高导致材料吸水。27. 加工过程中，应严格控制环境，确保在 ≤3s 范围内，避免污染导致材料性能下降。28. 加工过程中，应严格控制设备，确保在 ≥98% 范围内，避免设备故障导致材料性能下降。29. 加工过程中，应严格控制人员，确保在 3. 标准范围内，避免人员操作不当导致材料性能下降。

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